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Integrated control of *Striga hermonthica* using *Parkia biglobosa* products and mycoherbicide (*Fusarium oxysporum)* in maize (*Zea mays* L.) in the savanna

Magani,[1]* I.E., Ibrahim,[2] A.[1], and Avav,[1] T.
[1]Department of Crop and Environmental Protection, University of Agriculture, P.M.B 2373, Makurdi, Nigeria.
[2]Department of Agronomy, Nasarawa State University of Keffi, Nasarawa State, Nigeria.

* Corresponding author e – mail: m.enochistifanus@yahoo.com

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ABSTRACT

Objective: To evaluate the efficacy of a granular mycoherbicide (*Fusarium oxysporum*) formulation and Parkia (*Parkia biglobosa*) products under greenhouse conditions for eventual use as an integrated *Striga* management package under field conditions in the Nigerian Savanna.

Methodology and results: Two maize varieties (Across 97 TZL and farmers' local) and two *Striga* seed density (5 and 10 c.c/pot) were used in two trials. Two and three *Striga* control methods (with and without *F. oxysporum* isolated from *Striga hermonthica* stems (Marley *et al.* 1999)); seed soaking for 20 minutes before planting in Parkia products (fruit powder, seed powder) and distilled water as control were used in the first and second trials, respectively. In the two trials, the design used was a randomized complete design with three (3) replications. Generally, the number of emerged *Striga* was significantly higher in fields planted with the farmers' local variety than in fields with Across 97 TZL in both trials and throughout the period of observation. The use of either *F. oxysporum* or Parkia products (fruit and seed powder) resulted in significantly fewer number of emerged *Striga*, lower *Striga* dry weight than their corresponding checks (No *Fusarium* and distilled water). The number of emerged *Striga* as influenced by *Striga* seed density (*Striga* infestation levels) was only significantly different at 56 days after sowing (DAS) in the first trial (evaluating *Fusarium*), while other periods of observation did not produce consistent results. However, in the second trial, (evaluating Parkia products), the higher Striga seed density (10c.c/pot) produced a corresponding higher number of emerged *Striga* plants than the lower density (5c.c/pot) throughout the period of observations, although the difference was not significant ($P<0.05$)

Conclusions and application of findings: The results demonstrate the high potential of using mycoherbicides and Parkia based products for the control of *S. hermonthica*. Parkia trees abound in the Savanna and thus products can be easily and cheaply obtained. Likewise, maize grits can be used to propagate *F. oxysporum* quickly and cheaply by the farmers' instead of using the more expensive potato dextrose agar. The implication of these findings is that farmers can easily adopt these practices in integrated management packages for enhanced control of the parasitic plant under field conditions.

Key words: *Striga*, biological, integrated control, mycoherbicide, Parkia products, maize.

INTRODUCTION

Striga hermonthica (Del.) Benth of the genus *Striga* (Scrophulariaceae) is endemic in the African savannas where it parasitizes cultivated crops such as maize, millet, sorghum, rice, sugarcane as well as pasture and wild grasses (Parker & Riches, 1993; Weber *et al*., 1995). It is the dominant parasitic weed species in the Nigerian savanna, occurring in ecological zones extending from latitudes 7 – 14^{0}N. It is one of the major threats to cereal production where severe damage can cause total crop loss in farmers' fields particularly under low fertility conditions (Lagoke *et al*., 1991; Ogungbile *et al*., 1998; Kim *et al*., 2002; Marley *et al*., 2002)

Previous research has identified several effective control technologies (Parker & Riches, 1993) that include planting resistant host crop cultivars, using leguminous trap crops, and improving and maintaining soil fertility (Kim *et al*., 1997; Debra *et al*., 1998; Sauerborn, 1999; Schulz *et al*., 2003). The ability of *Striga* spp to produce a tremendous number of seeds, which can remain viable in the soil for more than 20 years, and their intimate physiological interaction with their host plants, are some of the main difficulties in the development of successful control measures that are acceptable to subsistence farmers. Although several control methods have been tried, so far none has given consistent, effective and economically feasible results when used alone (Eplee *et al*., 1991). Consequently, the parasite remains one of the major biotic constraint to food production in the Sahelian and savanna zones of Africa.

Biological control, especially using insects and fungal pathogens against parasitic weeds, has gained considerable attention in recent years and appears to be promising as a viable supplement to other control methods within an integrated approach. Fungi of numerous pathogens have received most attention for biological control of *Striga* spp. (Abbasher *et al*., 1995; Ciotola *et al*., 1995; Kroschel *et al*., 1996; Marley *et al*., 1999). However, the use of plant products for the control of *S. hermonthica* is limited, though the effect of plant materials especially neem (*Azadiractha indica*) products have been reported to have significant effects on plant parasitic organisms, especially insects (Jackai *et al*., 1992; Gahukar, 2000); fungi (Devi & Prasad, 1996; Agbenin, 2002), and to some extent nematodes (Abdel – Razek & Gowen, 2002; Amadioha, 2002).

The control of *Striga* is more likely to be achieved by combining a range of individual component technologies into integrated packages that will give flexible and sustainable control over a wide range of bio-physical and socio-economic environments (Berner *et al*., 1996; Schulz *et al*., 2003). Therefore, the principal objective of this study was to evaluate the efficacy of a granular mycoherbicide (*F. oxysporum*) formulation and Parkia (*Parkia biglobosa*) products under greenhouse conditions for eventual use as an integrated *Striga* management package under field conditions in the Nigerian savanna.

MATERIALS AND METHODS

Preparation of pathogenic fungi (mycoherbicide): Biological control using *Fusarium oxysporum* (isolate PSM 197) as mycoherbicide was reported (Marley *et al*., 1999, 2000; Marley & Shebayan, 2005). *F. oxysporum* (isolate PSM 197) was isolated from *S. hermonthica* stems and single spore isolates made into stock cultures (Marley & Shebayan, 2005). The cultures are maintained on potato dextrose agar (PDA) amended with streptomycin (Difco) and stored in the refrigerator at 4^{0}C at the Institute for Agricultural Research, Samaru, Zaria. Fresh starter cultures are made when required. The biocontrol agent was produced on gritted maize grains (whole grain-broken into smaller pieces) in the laboratory as described by Marley *et al*. (1999). Gritted grain (500g) was placed in 1L flat – bottomed flasks each containing 250ml of sterile distilled water. Flasks were shaken to ensure that the substrate was properly moistened and excess water was poured off prior to autoclaving for 1hr at 121^{0}C (103.5kPa). After cooling, each flask was inoculated with three agar plugs (5mm diameter) of isolate PSM 197 and then incubated at 28^{0}C for 7 days. During the incubation period, each flask was shaken daily (10 hr) to enhance full colonization of the grains by the pathogen. Colonized grains were harvested 14

days after inoculation and stored in refrigerator at 4^0C, to be used when required as the mycoherbicide.

Preparation of Parkia based products: Matured and dried Parkia fruits were collected from North Bank, Makurdi. The Parkia fruits were pealed and the fruit pulp and seed separated. The fruit pulp and seeds were allowed to dry under sunlight for about 14 days. Thereafter, they were separately ground into fine powder (<1mm) and stored dry until use.

Green house evaluation: Two pot experiments were conducted using two maize varieties (Across 97 TZL (resistant) and farmer's local (susceptible)) at two *Striga* seed density (5 and 10 cc/pot) in the green house of the College of Agriculture, Yandev (7^0 14'N and 8^0 37'E) in the Southern Guinea Savanna ecological zone of Nigeria. In the two trials, *S. hermonthica* seeds collected in 2007 were cleaned to remove chaff by passing them through a 250µm sieve. The *Striga* seeds were then mixed with sand that had been sieved through a 250µm screen at a ratio of 1:39 by weight to obtain approximately 3000 germinable seeds per gram of sand to seed mixture as described by Berner *et al*. (1997). This formed the stock. Each experimental pot (19cm wide x 22cm high) was filled with soil (5kg/pot) obtained from a field belonging to the Experimental Farm of the College of Agriculture, Yandev, that had no history of *Striga* infestation. The soil was air dried, and then one gram of the sand/seed mixture as per the different seed density (5 and 10 c.c/pot) required was placed in each pot and thoroughly mixed with soil before maize seeds were placed in the hole and watered to saturation with tap water before planting. In the two trials, planting was done on the 22nd of July 2008 and was terminated 95 days after sowing (DAS). Compound fertilizer 15:15:15 (N:P:K) and urea was applied 21 and 42 DAS, respectively, at the recommended rate of 64kg N/ha. The temperature in the greenhouse varied from 25 to 30^0C. The maize plants were regularly watered as necessary for optimal development.

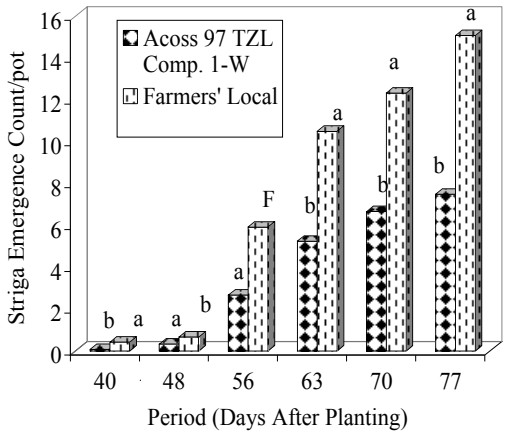
Experiment I: This was to test the differential response of maize varieties to *Striga* control using *F. oxysporum* (mycoherbicide). A total of 24 pots were used for this experiment. To each of the pots (containing seed/sand/soil) as described above, 2g of *F. oxysporum* was subsequently added and mixed thoroughly before planting. In this trial, the treatments compared were use of *F. oxysporum* and no *Striga* control. The pots were arranged in a randomized complete design on a bench in the green house with three (3) replications. After pre-irrigation for one (1) week, maize seeds (Across 97 TZL and the farmers' local) were sown.

Experiment II: This was to test the differential response of maize varieties to *Striga* control using Parkia based products applied as seed coating/soaking. A total of 27 pots were used for this experiment. The Parkia (400g) each of the base products (fruit powder, seed powder) was dissolved in one (1) litre of distilled water and stirred to form a slurry. To the slurry, 1000 maize seeds were introduced and allowed to soak for 20 minutes before planting. The treatments compared were Parkia fruit powder, Parkia seed powder and soaking in distilled water as check. The same design and arrangement as described for expt. 1 above was used.

Data collection and analysis: Observations made included number of days to first *Striga* emergence, percent (%) maize germination, crop reaction score, maize plant height, shoot dry weight and Striga dry weight. The data collected were subjected to analysis of variance and means compared using Least Significant Difference (LSD) at 5% level of probability.

RESULTS AND DISCUSSION

The number of emerged *Striga* varied significantly with maize variety throughout the period of observations, being higher in the farmers' local variety than Across 97 TZL (figure 1 and 2). In the context of this paper "resistant" maize refers to host cultivars that are less attacked in terms of damage and number of emerged *Striga* plants (Parker & Riches, 1993). Variety Across 97 TZL, being resistant, has been reported to produce lower amounts of germination stimulants to their root exudates, leading to smaller numbers of attached parasites and/or later attachment of the parasites to the host (Gurney *et al*., 2002). Parker and Riches (1993) suggested three ways by which crop cultivars resist *Striga* attack, i.e. mechanical barrier in the host root cells that prevent the haustoria from attaching; anti-haustoria factors; and low stimulant production. The mechanism of resistance of Across 97 TZL may be through low stimulant production since fewer *Striga* plants were recorded with this cultivar in these trials.



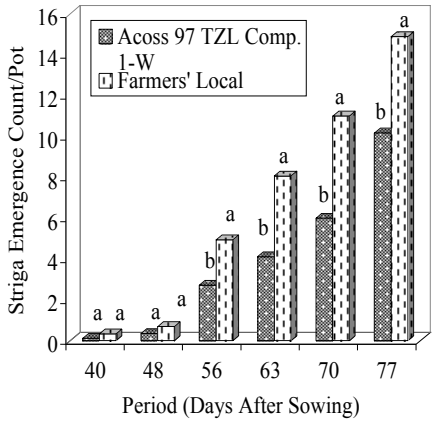
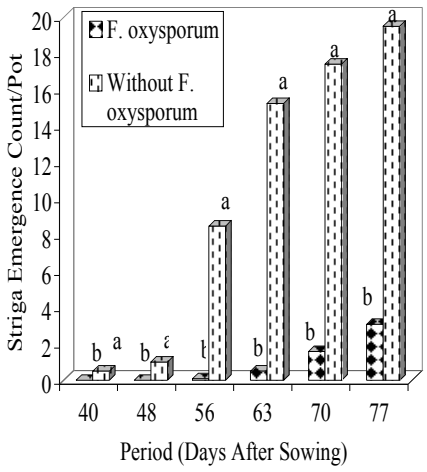


Figure 1 (left): Number of emerged Striga as influenced by maize varieties in the *F. oxysporum* pre-plant inoculation trial in the green house at Yandev, 2008. **Figure 2** (right): Number of emerged Striga as influenced by maize varieties in the pre-plant seed soaking with Parkia products' trial in the green house at Yandev, 2008. For each period of observation (days after sowing) columns with same letters are not significantly different at P<0.05.

There were also significant differences in *Striga* emergence as influenced by the different control methods (figure 3 and 4). In the first experiment (pre-plant *F. oxysporum*), the number of emerged Striga was significantly higher in the control (no *Fusarium*) (figure 3). This result confirms earlier works by Marley *et al*. (2004) who observed complete inhibition of *S. hermonthica* emergence when a powder consisting of Fusarium chlamydospores was added to the soil at sowing or when sorghum seeds coated with chlamydospores were sown. Marley *et al*. (2004) also reported that spot application mycoherbicides at sowing of 5g of *Fusarium* – colonized grains in each planting hole, equivalent to 165kg/ha, were highly effective against *S. hermonthica*. In the second experiment maize seeds soaked in Parkia fruit powder had significantly lower number of emerged *Striga* while the highest emergence was for seeds soaked in distilled water (figure 4). This result shows that Parkia based products possess a strong allelopathic potential and exhibits strong inhibition to *Striga* emergence. A number of allelochemicals identified from dodder (*Cucusta* spp.) plant, including terpenes, phenols, phenolic acids, long-chain fatty acids, and lactose are similar to those contained in Parkia products (Tran *et al*., 2008). These chemicals have been previously reported to inhibit plant growth and possess strong herbicidal activities (Agelini *et al*., 2003; Nishida *et al*., 2005). (Patterson, 1981; Elzaawely *et al*., 2005).



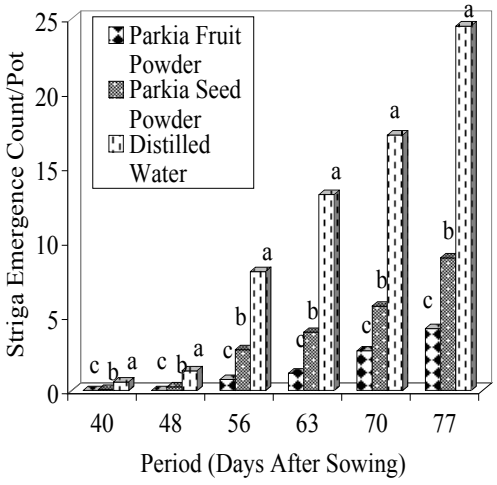
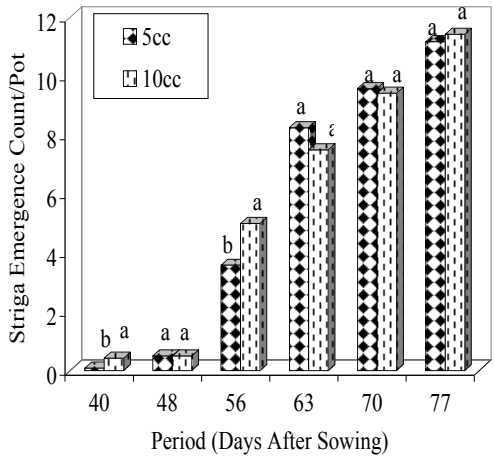


Figure 3 (left): Number of emerged Striga as influenced by control using *F. oxysporum* as pre-plant inoculation in the green house at Yandev, 2008. **Figure 4** (right): Number of emerged Striga as influenced by Striga control by pre-plant seed soaking in Parkia products in the green house at Yandev, 2008. For each period of observation (days after sowing) columns with same letters are not significantly different at P<0.05.

The effect of *Striga* seed density (infestation levels) on the number of emerged *Striga* was only significantly different at 56 DAS, while other periods of observations did not produce consistent results in the experiment on control using *F. oxysporum* (figure 5). However, in the experiment using Parkia products, the higher *Striga* seed density (10c.c/pot) produced a corresponding higher number of emerged *Striga* than the lower density of 5 c.c/pot throughout the period of observation (figure 6), though the difference was not significant. This result confirms the reports of Emechebe *et al*. (1991) and Magani *et al*. (1994) on *Alectra* and *Striga gesnerioides* infecting cowpea.



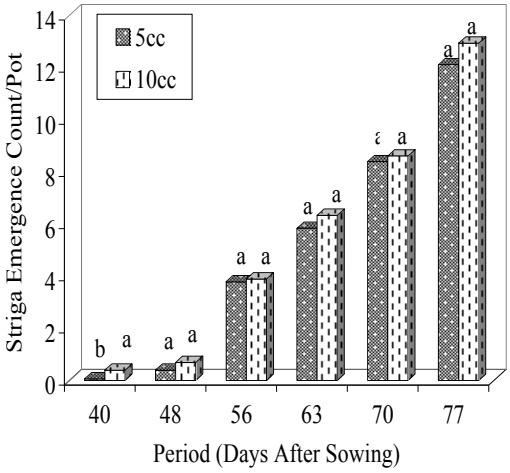


Figure 5 (left).: Number of emerged Striga as influenced by seed density and control using *F. oxysporum* pre-plant inoculation in the green house at Yandev, 2008.**Figure 6 (right):** Number of emerged Striga as influenced by seed density control bysoaking maize seed in Parkia products in the green house at Yandev, 2008. For each period of observation (days after sowing) columns with same letters are not significantly different at P<0.05.

Maize plant height, *Striga* and maize dry weight at harvest (95 DAS) as influenced by *Striga* seed density in both experiments are presented in figures 7 and 8. Maize plant height and dry weight were significantly affected by *Striga* seed density with 5c.c/pot resulting in significantly taller maize plants and higher dry weight than 10c.c/pot. However, there was no significant difference between the effects of *Striga* seed density with respect to *Striga* dry weight

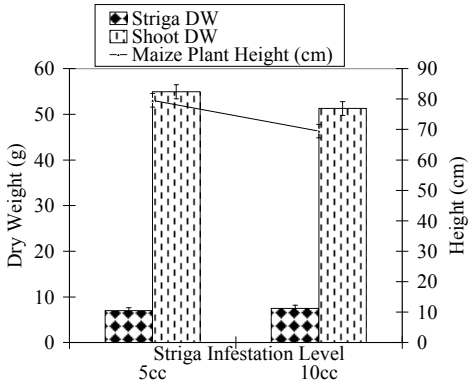


Figure 7 (left): Maize plant height, Striga and maize shoot dry weight at harvest as influenced by Striga seed density and control using *F. oxysporum* pre-plant inoculation in the green house at Yandev, 2008. **Figure 8 (See link):** Maize plant height, Striga and maize shoot dry weight at harvest as influenced by Striga seed density and control through soaking in Parkia products in the green house at Yandev, 2008. Error bars represent the standard error of means. At the same seed density, columns with same letters are not significantly different at P<0.05.

The influence of varieties on maize plant, *Striga* and maize dry weight at harvest are presented in figures 9 and 10. In the two experiments, cultivar Across 97 TZL resulted in significantly taller plants as well as higher maize dry weight that the farmers' local variety. The farmers' local variety had significantly higher *Striga* dry weight than Across 97 TZL. This may be attributed to lower number of emerged *Striga* associated with variety Across 97 TZL when compared to the farmers' local variety.

The different *Striga* control methods using *Fusarium* and Parkia products significantly affected maize plant height, *Striga* and maize dry weight (figures 11 and 12). The use of either *F. oxysporum* or Parkia products resulted in significantly lower *Striga* dry weight than their corresponding non treated checks (No *Fusarium* and soaking in distilled water). The low *Striga* dry weight in plots treated with *F. oxysporum* and Parkia based products is direct effect of good control of the parasite achieved by these treatments. This is attributable to the suppressive ability of the allelochemicals contained in Parkia products (Lane *et al.*, 1991; Kambou *et al*., 1997); while the use of *Fusarium*-based mycoherbicide has been reported to give complete inhibition of emergence when chlamydospores powder was added to the soil at sowing (Ciotola *et al.*, 2000). In both experiments, the respective non-treated controls (No *Fusarium* and soaking in distilled water) resulted into shorter maize plants with lower dry weight. This result supports that of Press *et al*. (1987) showing that prior to emergence, *Striga* depends entirely on its host for carbon, and even after emergence, two-thirds (2/3) of its carbon requirements still comes from its host. Another factor leading to reduced dry matter production by the host is the possible reduced photosynthetic activity as well as competition for growth resources in heavily infested plants between the parasite and the host.

CONCLUSIONS

The study results demonstrate the high potentiality of using mycoherbicides and Parkia based products for the control of *S. hermonthica* by spot application or seed soaking, respectively, at sowing. The Parkia trees are abundant within the savanna and thus their fruits can easily be procured. Similarly, the use of maize grits, which is readily available to locally propagate *F. oxysporum*, makes it quite cheap for farmers' instead of using potato dextrose agar. This implies that farmers could adopt the tested control methods and integrate them within other management practices such as host plant resistance and other cultural practices to enhance control of *S. hermonthica*.

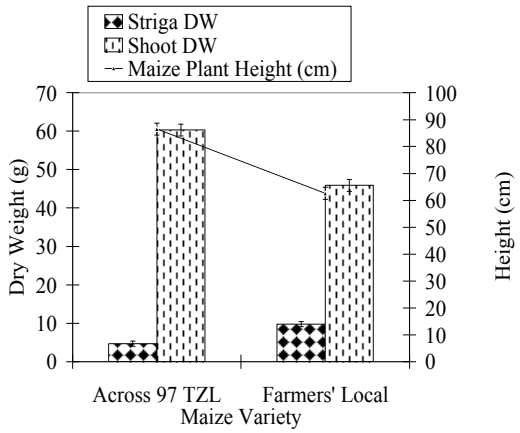


Figure 9 (left): Maize plant height, Striga and maize shoot dry weight at harvest as influenced by varieties and Striga control using *F. oxysporum* pre-plant inoculation in the green house at Yandev, 2008. **Figure 10 (See link):** Maize

plant height, Striga and maize shoot dry weight at harvest as influenced by varieties and Striga control by soaking maize seed in Parkia products. Error bars represent the standard error of means. At the same seed density, columns with same letters are not significantly different at P<0.05.

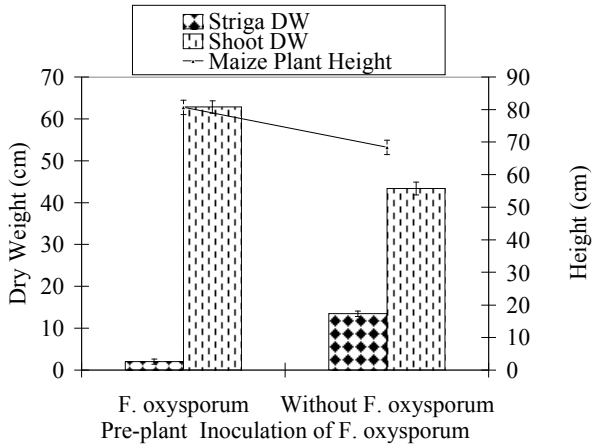


Figure 11 (left): Maize plant height, *Striga* and maize shoot dry weight at harvest as influenced by *Striga* control using *F. oxysporum* pre-plant inoculation **Figure 12 (See link)**: Maize plant height, Striga and maize shoot dry weight at harvest as influenced by Striga control by seed soaking in Parkia products. Error bars represent the standard error of means. At the same seed density, columns with same letters are not significantly different at P<0.05

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